Machine Learning in Solar and Space Physics

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Movie Courtesy Larry Manley
“We had succeeded in creating the world’s most powerful pattern-recognising supercomputer, and it existed in the linked intelligence of all the people who had logged on to our website: and this global brain was processing this stuff incredibly fast and incredibly accurately.”

-- Kevin Schawinski
Problems well-suited for machine learning

• Classification
  • e.g. different types of galaxies in image data
  • e.g. different types of solar features in image data

• Event detection – particularly needle-in-a-haystack events
  • e.g. reconnection events in time series data

• Clustering
  • e.g. different varieties of solar wind from in situ data
  • e.g. different categories of line profiles in spectral data

• Prediction
  • e.g. the occurrence of solar flares
Step 1: Identify active region
Step 2: Characterize features of interest
Step 2: Characterize features of interest
Step 3: Machine-Learning Algorithm for Classification

Convolutional Neural Network

source image → filter → nonlinear transformation → downsample → vectorize → total feature vector → threshold
Step 4: Define the task

GOES X-Ray Flux

- 0.5 - 4.0 Å
- 1.0 - 8.0 Å

Flux (Watts m⁻²)

September 5 2017 - September 7 2017
Step 5: Machine-Learning Algorithm for Prediction

Support Vector Machine

total flux

area

Cortes and Vapnik (1995)
Pedregosa et al. (2011)
Step 5: Machine-Learning Algorithm for Prediction

Support Vector Machine

Cortes and Vapnik (1995)
Pedregosa et al. (2011)
Step 5: Machine-Learning Algorithm for Prediction

Support Vector Machine

Jonas et al. (2017), in review
Bobra & Ilonidis (2016)
Bobra & Couvidat (2015)
Bobra et al. (2014)

Cortes and Vapnik (1995)
Pedregosa et al. (2011)
Daniel K. Inouye Solar Telescope
First light: 2019

~25 TB/day for ~50 years
400 PB total data volume

Ruth Kneale / DKIST
astropy
A Community Python Library for Astronomy

sunpy

spacepy

Plasmapy

spacepy, https://pythonhosted.org/SpacePy/, Morley et al. (2011)